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Actor-network analysis of change making in Finnish energy transitions

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1. Introduction

Technological advancements are driving massive changes in the energy field in many countries; renewable energy production technologies, in particular, are diffusing extensively as their cost declines. Climate change mitigation is a key driver for change, as nation states respond to international agreements by drafting national energy and climate strategies which support the shift towards renewable energy production and consumption. Traditional energy technologies continue to dominate, while many truly novel technologies still require significant development and maturation to correspond to long-term sustainability transitions.

In innovation terms, disrupting established ways of doing business (Christensen et al., 2015) and eventually replacing them with the upmarket movement of seemingly simple technological alternatives is sought for. Given the electrification and datafication of the energy sector (e.g. AFRY, 2020), there are further opportunities for open innovation that reach beyond the boundaries of companies and existing markets (Chesbrough, 2003) where the vested interests of dominant actors continue to have an effect. Indeed, the development of parallel and compatible technologies combined with the urgent need to mitigate climate change provide renewed impetus for reaching novel technological solutions. Thus, experimentation with changing configurations of technologies and actors is required to break from the established and restrictive operating methods of strategic action fields in industries (Fligstein & McAdam, 2011). For instance, novel configurations of information technologies and electric mobility have become a driving force for change (Köhler et al., 2019).

Using network analysis, this article examines the opportunities for novel forms of innovation by breaking down the sustainable energy technologies involved in planned experiments into their characteristics (e.g. energy source, technology, pathway, etc.) and connecting them to the actors involved in their development. Network analysis provides a technical application for reviewing large numbers of cases, and has been applied in transitions studies with a focus on social actors (Caniëls and Romijn, 2008; Manders et al., 2018). As a methodological approach, actor-network theory (ANT) enables the consideration of non-humans as actors in their own right (see e.g. Callon, 1986; Latour, 2005; Law and Hassard, 1999), supporting the examination of networks involving technologies, organizations and locations — a useful procedure in the realm of energy experiments. Markard et al. (2012), studying sustainability transitions, acknowledge that ANT can offer a useful and complementary way to approach the field; Geels et al. (2018) discuss ANT in terms of adaptation of innovation, while Geels and Deuten (2006) use ANT to examine knowledge diffusion in their study of local intermediary actors.

In our work, network analysis is used to explore how novel sustainable energy technologies are expected to emerge by 2030. We pay particular attention to the characteristics of energy technologies that require experimentation and to the actors who are considered key players in their development. Using data from an extensive stakeholder involvement process (i.e. a 'transition arena') conducted in Finland in 2017, we construct networks of actors and technological characteristics that show how simple technological characteristics can move upmarket and transcend established market arrangements. The methodological approach of this article can be applied in studies in other fields which are experiencing disruptive change.

2. Case: Energy Transition Arena

An energy transition arena was held in Finland in 2017 by the Smart Energy Transition research project in order to engage key change makers in the field in a co-creative visioning process (Hyysalo et al., 2019; Matschoss et al., 2020). The transition arena methodology is based on the theoretical framework of transition management, which leans on the idea of anticipating and coordinating sustainable transition processes (e.g. Loorbach, 2010, Frantzeskaki et al., 2012).

Transition arena participants comprised individuals considered to be in positions in which they could act as "frontrunners" of change based on novel ideas (Rotmans and Loorbach, 2009, p. 189), including representatives of large companies and SMEs, civil servants, politicians, NGO representatives, active citizens and academic researchers; incumbent actors were deliberately not targeted for inclusion (see Hyysalo et al., 2019). The arena was organized as a series of workshops, each representing a particular step in a process involving a number of stages: first, forming a vision for the country by 2030; then establishing transition goals, sketching pathways towards reaching the vision and outlining individual steps; and, finally, proposing detailed actions:

- **Transition vision**: In 2030, Finland will be a proactive pathfinder that develops winning solutions to global environment and energy challenges. Finland utilizes the opportunities of digitalization, new services, citizen participation and novel research.
- **Pathway goals:** 1) Coal is phased out by 2030; 2) Creating 2000 MW demand-response capacity in electricity; 3) Creating 2000 MW demand-response capacity in heating; 4) Halving building net-energy use; 5) Reducing household energy use by 15% with behaviour change measures; 6) 750,000 alternative energy vehicles on Finnish roads by 2030; 7) Reducing total mileage by 10% through mobility as a service; 8) Doubling the clean technology exports of Finland (Hyysalo et al., 2019).

Each pathway included co-created suggestions for experiments that would support the transition, and our work builds on the network analysis of those experiments. A total of 30 experiments were outlined in the Finnish Transition Arena. Our research targets were to analyze the actors connected with specific pathways and the technology applied in order to study how key actors are positioned and interconnected in the energy field.

The examined transition experiments were coded according to their key characteristics: energy source, technology, pathway, actor and geographical scale. One of the authors of this article executed the first coding and the other authors verified it. In preparation for network analysis, codes in specific experiments were paired, which contributed to 555 code pairs of varying occurrences. Most occurring code pairs concerned demand response, termination of coal, business, cities and researchers.

The code pairs are used as data in Gephi visualization and exploration software (Bastian et al., 2009). Each code is represented as a 'node' and, in the network visualization in Figure 1, the size of the node represents its connections to other nodes; the frequency of these connections is reflected in the width of the line (i.e. ‘edges’). A modularity algorithm (Blondel et al., 2008) was applied to identify clusters of codes and the Yifan Hu layout (Hu, 2005) to map results in the graph.

3. Actor-networks for change

A number of parallel transition dimensions can be distinguished in the findings of the network analysis, depicted in Figure 1. These are visualized in six coloured clusters, which connect actors with other characteristics of sustainable energy systems. The cluster in light green focuses on individual behaviour change, the purple cluster on the demand response being constructed by industry, the orange cluster on terminating coal as a source of energy in cities, the blue cluster on experimenting with provision of charging infrastructure for electric mobility in communities, the dark green cluster on promoting energy efficiency in major cities, and the red cluster on constructing a market for clean tech exports and imports.

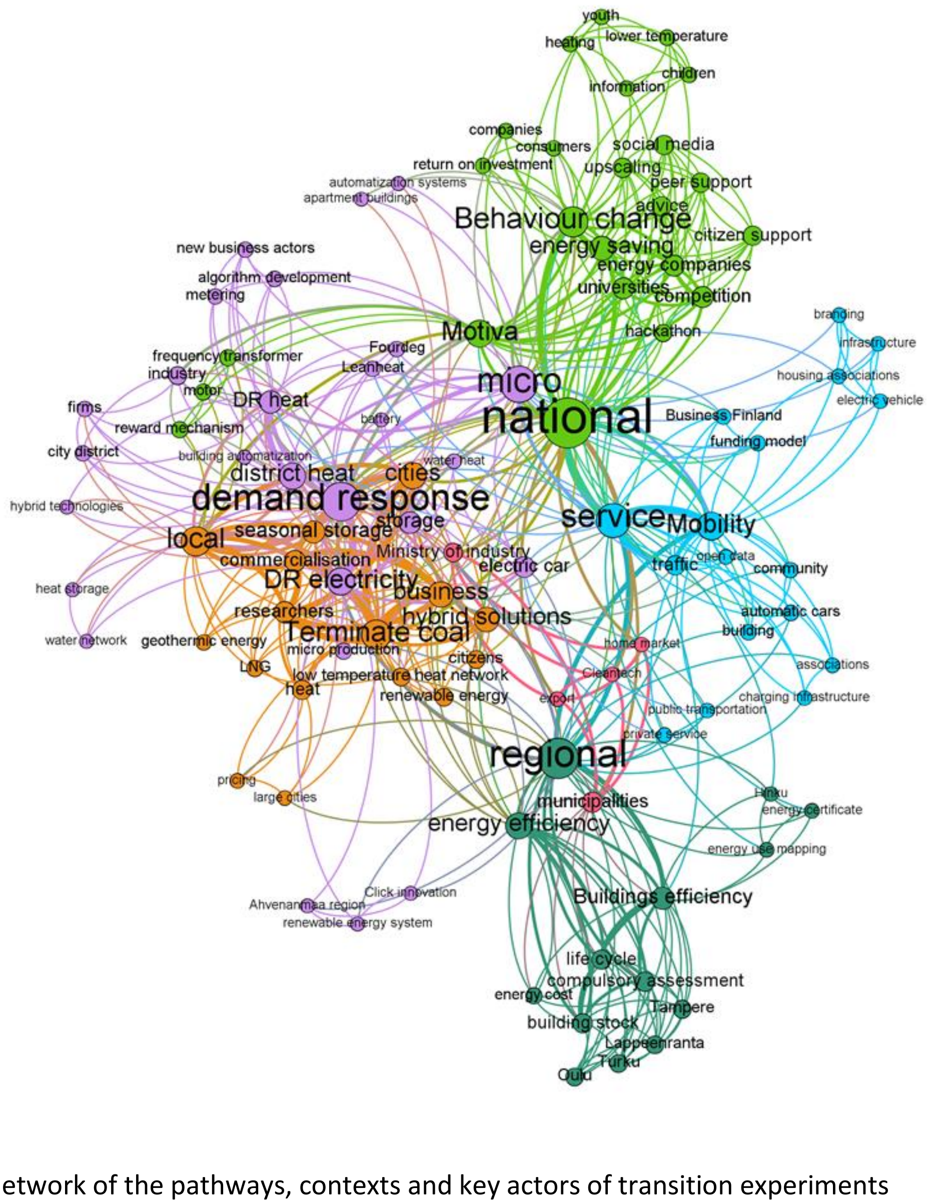

Figure 1. Network of the pathways, contexts and key actors of transition experiments

National level configurations are seen to connect many actors in the energy field that focuses on change of behaviour (light green cluster). Motiva - a state-owned company that advances energy efficiency and sustainable energy solutions - is a focal point that connects behaviour change to demand response in heat and electricity (purple cluster), the termination of coal at the regional level (orange cluster), and mobility services (blue cluster). Many other actors are envisioned as being involved in behaviour change: energy companies and universities in particular provide advice and support as well as creating new information in competitive settings and hackathons; companies and consumers interplay in considerations of returns of investment; and the involvement of youth and children relates to initiating future practices such as maintaining lower temperatures in housing. Behaviour change is in this respect seen to result from an information mechanism involving key information suppliers and targets rather than more binding policy measures (Baldwin and Cave, 1999).

Demand response (the purple cluster) is constructed by industry actors and firms and is distinguished by technological development such as metering, storage and hybrid technologies. It is envisaged that new business actors will introduce ICT technologies such as algorithms and IoT computing. In contrast with the cluster focusing on behavioural change, consumers and citizens are not involved here as actors or targets.

Terminating the use of coal as an energy source is to a large degree a local issue (the orange cluster) with close connections to demand response (the purple cluster). Cities and businesses are key actors in the development of sustainable energy solutions such as seasonal storage, geothermal energy, low temperature two-way heat networks and liquefied natural gas (LNG) in the attempt to terminate coal usage. Researchers are involved in the commercialization of energy services and citizens in the uses of new energy solutions.

Mobility services (the blue cluster) connect to national and regional contexts (light and dark green clusters), and focus on traffic, public and private transport, buildings and charging infrastructure. The field is polarized in terms of actors, with Business Finland (a government organization for innovation funding and trade, travel and investment promotion) being supported by industrial communities and associations concerned with automated cars and charging infrastructure, while challenged by housing associations over infrastructure relating to electric vehicles in general. Businesses are perhaps surprisingly not considered key actors in this cluster.

Major Finnish cities and the Hinku network of municipalities aiming for carbon neutrality are to be key actors in the energy efficiency field, which has a regional focus (dark green cluster). Activities relate to the energy efficiency of building stock, its assessment and mapping as well as certificates. The energy efficiency of buildings is also at the nexus of the demand response (purple cluster), termination of coal (orange cluster) and mobility services (blue cluster).

The cluster on Cleantech (in red) is centrally positioned but represents more a business dimension in sustainable energy than an independent energy form. It looks at exports and imports and connects with national and regional markets. Municipalities and the ministry responsible for the development of industry are to be key actors in the field, which highlights the public interest in promoting international competitiveness and public ownership of energy production.

4. Discussion and conclusions

The transition towards sustainable energy requires that the foundations of established energy forms and markets be rethought. New technologies have matured in the field and reconfigurations between actors and technologies provide opportunities for the emergence of new strategic action fields for sustainable energy (Fligstein & McAdam, 2011). Our analysis reflects that such disruption is not accomplished through the development of new and superior products but is, rather, the systemic outcome of many parallel and networked developments (see Christensen et al. 2015). These result in market reorganization and the potential emergence of new strategic action fields. Innovation activities in such experimental transitions settings are open in character as actors make use of external ideas and form new partnerships (Chesbrough 2003).

A move towards sustainable energy consists not only of the development of new technologies but also requires changes in how energy is consumed. This is highlighted in our analysis of actor networks, which shows that the goal of 'behaviour change' brings together many different actors, ranging from developers to future providers and users of energy. The other networks are more focused in terms of energy fields and actors, and concern demand response, termination of coal in energy production, mobility services, energy efficiency and cleantech. The data used in this analysis are drawn from experts' grounded views on the experiments required to support sustainable energy transitions. In this respect, such experiments can connect on-going developments to prospective near-future innovations and systemic sustainability transitions.

When fields are being reconfigured due to external pressure such as mitigation of climate change, combined with technological opportunities such as the electrification and datafication of the energy sector, it is a useful procedure to examine connections between actors and technologies. Actor-network analysis provides a rationale and systematic methodology for this as it supports the deconstruction and reconstruction of fields which are being reconfigured. Such approaches can provide greater understanding of systemic change and transitions (Köhler et al. 2019).

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